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**EPTD DISCUSSION PAPER NO. 46**

**DETERMINANTS OF LAND USE CHANGE: EVIDENCE FROM  
A COMMUNITY STUDY IN HONDURAS**

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## **ABSTRACT**

This study investigates the micro-determinants of land use change using community, household and plot histories, an ethnographic method that constructs panel data from systematic oral recalls. A 20-year historical timeline (1975-1995) is constructed for the village of La Lima in central Honduras, based on a random sample of 97 plots. Changes in land use are examined using transition analysis and multinomial logit analysis. Transition analysis shows that land use transitions were relatively infrequent in areas under extensive cultivation, but more so in areas of intensive cultivation; and that most changes favored intensification. Econometric analysis suggests that land use intensification was influenced by plot level variables (especially altitude, slope, distance to a road and tenure), farm level variables (human capital, farm size, and ownership of productive implements), and by community variables (especially presence of technical assistance programs).

To the extent these results are found to be more broadly representative, they suggest that there may be good potential to promote income-enhancing horticultural development through investments in technical assistance and education in similar communities elsewhere in Honduras. The study concludes that the plot history approach is a potentially valuable tool for investigating the underlying causes of change in land use at the micro-level. The method is particularly well adapted to situations where the availability of data is poor. It is also suggested that the approach would have additional benefits when replicated over a large number of sites as this would allow integration of higher order determinants (e.g. national policies and market incentives) while expanding the applicability and representativity of findings.

## CONTENTS

Abstract .....	1
1. Introduction .....	3
2. Conceptual Framework and Hypotheses .....	5
Community Factors .....	7
Farm Characteristics .....	9
Plot Level Characteristics .....	10
3. Methods .....	13
Data Collection .....	13
Sampling .....	15
Analytical Methods .....	16
<i>Transition Analysis</i> .....	16
<i>Econometric Model</i> .....	17
<i>Econometric Problems</i> .....	22
4. Results .....	24
Community Level Changes .....	24
Household Level Changes .....	25
Plot Level Changes and Transition Analysis .....	29
Econometric Analysis .....	36
<i>Regression Results</i> .....	36
<i>Diagnostics</i> .....	38
<i>Discussion of Results</i> .....	42
5. Conclusion .....	50
Summary of Findings .....	51
Policy Implications .....	51
Research Implications .....	54
References .....	56

# **DETERMINANTS OF LAND USE CHANGE: EVIDENCE FROM A COMMUNITY STUDY IN HONDURAS**

Gilles Bergeron and John Pender

## **1. INTRODUCTION**

This study investigates the determinants of land use change in one community in Honduras. Land use is defined here as a generic type of land cover—forests, pasture lands, and annual croplands are such types.<sup>1</sup> Change in land use can have far reaching consequences for farmers' welfare as well as the environment. For instance, conversion of a forest or pasture into irrigated cropland may increase farmers' incomes, but may also increase soil erosion, reduce plant bio-diversity, or lead to environmental pollution. On the other hand, intensification of land use (e.g., through terracing) may be associated with investments in land improvement that restore fertility to depleted lands (Scherr and Hazell 1994; Pender 1998). Given such wide ranging impacts it is important to understand how land managers arrive at their land use decisions, so that the potential benefits can be exploited while minimizing the negative consequences associated with such change.

Land use decisions are generally viewed as a function of both macro- and micro-level processes (Land Use Cover and Change [LUCC] Working Group 1996). The effects of macro-level factors (defined here to include land policies, markets and trade,

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<sup>1</sup> We distinguish land use from land management, as the latter refers to the practices realized within a particular type (e.g., which type of crop is grown in annual cropland).

aggregate population growth and technology development) on land use decisions have been relatively well studied (Capistrano and Kiker 1995; Turner et al. 1995). By contrast, the effects of micro-level factors (defined here to include to the land's bio-physical characteristics, the human and economic endowment of the farming household and community characteristics), and their importance relative to macro-level factors, have been little examined. This is the task we undertake here.

Our approach to the analysis of land use change begins with the identification, within homogeneous agroecological zones, of the various "pathways of development" adopted by rural communities over a given period of time (Scherr et al. 1996). Once the basic pathways are identified, they are individually analyzed using the plot history method (Bergeron and Pender 1996). To test the approach, a hillside region of central Honduras was selected. Several different pathways were identified using secondary data and community survey data (Pender, Scherr, and Duron 1999).<sup>2</sup> This paper presents a case study of a particular village in central Honduras, La Lima, which is representative of the "horticultural development" pathway. Besides the analysis of this case, the purpose of this paper is to demonstrate the application of the plot history method to a concrete situation, and its usefulness in understanding processes of land use change in general. Although La Lima represents only one particular development pathway, the method can be applied more broadly to study the causes and implications of land use change in different development pathways.

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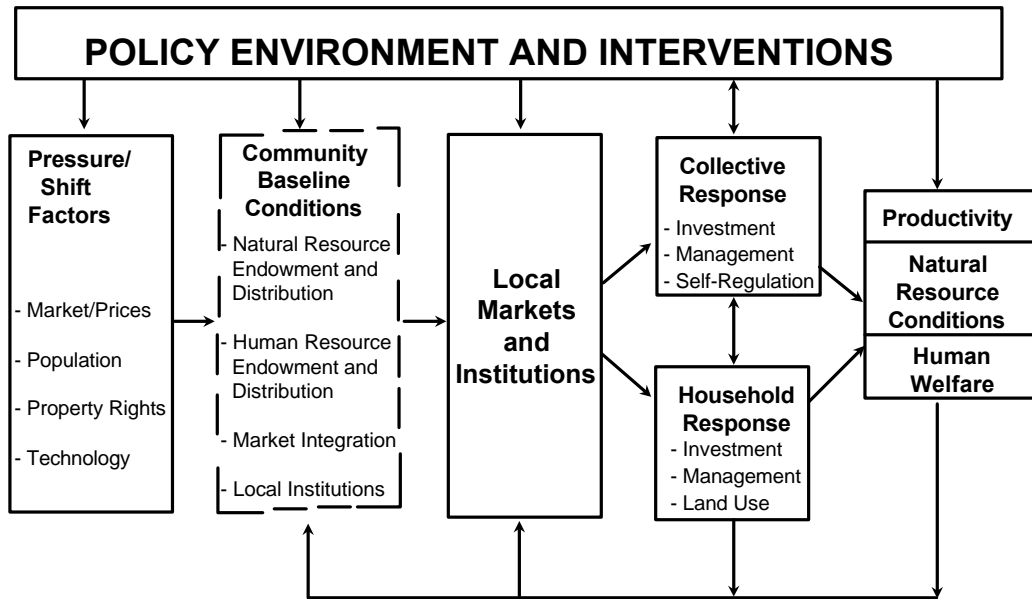
<sup>2</sup> Pathways identified included: 1) basic grain stagnation; 2) basic grain expansion; 3) forestry specialization; 4) non-farm employment; 5) coffee expansion; and 6) horticultural intensification (Pender et al. 1999).

## 2. CONCEPTUAL FRAMEWORK AND HYPOTHESES

Our general conceptual framework draws from the theory of agricultural change as developed in the work of Boserup (1965), Ruthenberg (1980), and others. Simply put, these authors argue that people adapt to changes in the conditions they confront, and that these adaptive responses are the main source of technical and institutional change in agriculture. Boserup stressed population growth as the dominant cause of agricultural development in underdeveloped countries: as population growth increases the scarcity of land relative to labor, reductions in fallow periods occur and labor use gets intensified. Technological and institutional innovations are expected to ensue, eventually resulting in further land use changes. Binswanger and McIntire (1987) and Pingali et al. (1987) expanded upon Boserup's model by introducing markets as another driving cause of agricultural intensification and land use change. Lele and Stone (1989) added the role of policy as a factor in shaping the nature and impacts of agricultural change, notably through the sanctioning of land use rights. Smith et al. (1994) emphasized exogenous technological developments, in addition to the preceding factors.

Our conceptual framework incorporates these macro-level factors under the term "pressure/shift variables" (Figure 1). We view these factors as the primary driving forces

Figure 1



Source: Scherr et al.

for land use change in a given plot. Their impacts are not equally distributed across space, however. As suggested in Figure 1, each individual community “conditions” the impact of these prime factors through its particular set of endowments; namely its biophysical characteristics, infrastructural resources, and social capital (local institutions and culture of production). These conditioning variables filter the pressures for change, by affecting the constraints and opportunities at the local level.

Once filtered by local variables, macro-level factors affect land use through their effect on local micro economic conditions. For example, national policies may foster the development of local credit markets, making it possible for farmers to invest in some plots and convert them to the production of cash crops. A downturn in cattle prices may



reduce the need for pasture, making large areas of land available for producing grain and other crops (Johnsson 1992). An agricultural extension policy that results in local yield increases may allow farmers to redirect some of their lands towards other purposes. The implications of exogenous changes on local land use are not always predictable, however: a new road may increase farmers' incomes and their incentive to invest in soil and water conservation; but it may also contribute incentives to deforest and quickly "mine" the soil's natural fertility. We suggest that the final outcome is premised upon the interplay among three levels of determination: the community; the farm; and the plot. Below we present a few hypotheses as to how this occurs.

## COMMUNITY FACTORS

From a microeconomic perspective, community-level factors (which include public infrastructure, market structures, local organizations, technology and population) affect farmers' decisions either by reducing costs per unit, by increasing local output prices or by affecting risk.

- 1) *Public infrastructure* (roads, irrigation facilities) may allow for the production of crops that were previously not considered, either because transport costs were prohibitive, because water was a limiting factor, or because production risk was too high without irrigation.
- 2) *Market structures*, including the presence of input suppliers, intermediaries, transport service and market outlets, affect land use by opening up the opportunities available to farmers. Local market imperfections—land or labor

- scarcities, lack of credit—may constrain adoption of new technologies and land use change, particularly for crops whose resource requirements exceed the family's labor and capital availability.
- 3) *Local organizations and institutions* may affect land use choices by regulating usage at specific points (e.g., near water sources) or by imposing restrictions on certain practices, such as use of agrochemicals or water. Producer associations or cooperatives may also reduce risk by capturing external resources, and providing representation. Local institutional mechanisms that facilitate the exchange of labor, such as “corvées,” may also enable farmers to allocate plots to higher intensity use.
  - 4) *Technical assistance*: technology diffusion among peers dominates in traditional farming but when new technologies are involved, farmers critically rely on advice from outside sources, and the availability of extension services may be a critical factor to intensification.<sup>3</sup>
  - 5) *Changes in population density* may affect land use choices by increasing the scarcity of land relative to labor, which creates pressure to reduce fallow periods and to invest labor effort in increasing land productivity. This may result in

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<sup>3</sup> That the technological and financial complexity of commercial farming accentuates farmers' dependence on professional sources has been corroborated by various studies, which showed a considerable readiness among small farmers to pay for technological or professional advice when it is directly linked to their commercial undertaking (Fearne 1990) but much less interest in issues like soil conservation, which have consequently remained difficult to privatize.

technological and institutional innovations (inventions, adaptations) that, once obtained, also create incentives for change.

## FARM CHARACTERISTICS

The farm internalizes a complex set of internal and external relations. On the one hand, farmers continuously respond to the economic, technological and political forces by which they are surrounded. On the other hand, they routinely exercise options within that range (Lowe, Ward, and Munton 1992). We assume here that the main determinants guiding farmers' selection of options are: 1) access to factors of production; and 2) individual motives and preferences, including their attitude towards risk and time horizon.

- 1) *Access to factors of production:* The decision to change land use must take into account all present and future costs and benefits entailed by this change, from improvement investments (if required) to the capacity to access labor and capital for future production under the new use. We therefore expect that the resource endowment of a household—the amount of land, fixed assets, labor and capital it can access—will affect its decisions about land use allocation. Farmers' skill can also be viewed as a factor of production: a farmer's relative abilities and training leads to variations in the implicit price of factors, which affects the relative costs of production, thus influencing land use choices. Decisions made within the household on building up their human capital will thus affect its set of relevant endowments.

- 2) *Personal motives:* The attitudes of farmers towards land use has been associated with lifestyle choices: part-time farmers earning an incidental proportion of household income from farming were found to be more likely to manage their land in a way that protects and enhances the traditional function of the farmed landscape (Lowe et al. 1992; Gasson 1983). Also, farm size is often cited as a factor *sui generis* influencing land use decisions. Some authors for instance noticed that larger farmers are more inclined to retain a traditional landscape than smaller ones (Newby et al. 1977), a fact that others explained as a function of whether or not farmers could avoid becoming engaged in the technological treadmill, and avoid initiating alterations to the landscape (Lowe, Ward, and Munton 1992). This suggests that the size of the farm and the relative importance of farming in the household economy are factors in land use decisions. The attitude of the farmer and other family members towards risk and their time horizon also guide their livelihood strategy, including how they use their land, the management technique they employ, and how they invest their resources, including their migration decisions. Unfortunately, in this study we did not have direct information on farmers' risk and time preferences, though these are likely affected by factors that we do take into account, such as farm size and household wealth (Binswanger 1981; Pender 1996). Still, differences in such factors may contribute to the unexplained variation in land use.

## PLOT LEVEL CHARACTERISTICS

Plots have both fixed and dynamic characteristics. Fixed attributes include slope, altitude, the presence of obstacles that reduce the area or make cultivation more difficult, and so on.<sup>4</sup> Dynamic features, by contrast, refer mainly (but not only) to the effect of human intervention. We distinguish three levels at which dynamic effects are acting: previous uses (state dependence); tenure and property regime; and the land's own physical process of change.

- 1) *State dependence*: The current allocation of land may be heavily influenced by how this land was used in the preceding period. The sunk costs of investments required to change land uses (e.g., land clearing, tree planting, etc.) are likely to inhibit changes in land use unless the benefits are very high. Furthermore, the marginal productivity gains of additional investments may be greater where some investment has already been made. For instance, once irrigation investment has been realized, investments in conservation measures may yield higher returns (Pender and Kerr 1998). Thus, an important predictor of land use at year<sub>t</sub> may be land use at year<sub>t-1</sub>.
- 2) *Property and ownership issues*: The property regime (e.g., titled land, ejido, etc.) and the sense of tenure security it provides may affect the willingness to invest, as well as the cost of investing if property status affects access to credit. Change in

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<sup>4</sup> Note, however, that as land gets transformed by usage and technology—e.g., slope modification devices such as terraces and contour plowing—these fixed features tend to become less determinant; and land that was formerly unused because of fixed characteristics can be brought under production—but this will require investment.

ownership may also have an impact on land use (Munton and Marsden 1991), although we assume here this is associated with the farm characteristics, captured in our analysis by household level factors. Finally the usufruct arrangements prevailing at a particular time in a plot—sharecropping, renting, etc. will also influence the owners' decision as to the use of that land. In many settings for instance rented land is less valued and protected than owner-occupied land (see, for instance, Pagiola 1996 for El Salvador).

- 3) *Physical transformations:* Dynamic forces may also emanate from bio-physical changes in the land itself. Environmental factors affect the type of land use that is possible, and changes in environmental factors can drive land use change. Until recently the environment tended to be viewed as “stable.” However, it is now more widely appreciated that climate and soils are not invariant (cf. Parry et al. 1989; Hekstra 1991). Climate (temperature, rainfall) is changing (although the magnitude of such change is not well known yet<sup>5</sup>). Soils are also changing, whether through natural processes (e.g., erosion, salinisation), through remote human activity (e.g., acidification<sup>6</sup>) or through direct human intervention (e.g.,

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<sup>5</sup> Changes in temperature affect the vegetation, as well as the microbial and animal species associated with these vegetation types (Holdgate 1991). All these factors affect land use, either because they change the potential of land to support different crop species, because they change the genetical basis of some of the species being managed, or because they induce change in the communities of microbes, plants and small animals that support vegetative life (Usher 1992).

<sup>6</sup> Acidification affects soil microfaunas: richer communities of species are found in neutral soils than in acid soils. This affects the decomposition of dead plant materials, which in turn affects soil structure and fertility (Edwards and Lofty 1972; Satchell 1983).

nutrient depletion and degradation). In this paper we do not consider the macro level causes of such change (e.g., climate change or acidification), but we include farmers' perception of change in fertility level; and the presence of severe erosion problems in the plot. We expect that a change in those variables reflects how present use of the land affects the soil and that this in turn has an influence on the future use of that land (Usher 1992, 33).

### **3. METHODS**

The plot history method (Bergeron and Pender 1996) was devised to confront the particular difficulties of investigating the history of land use change in data-poor environments. Our approach reconstructs local history at three levels: plot, household and community. The land itself being our main unit of analysis, the method centers on the elaboration of an appropriate plot sampling approach, and of appropriate modes of data collection. These are briefly detailed below.

#### **DATA COLLECTION**

A challenge in the construction of multi-level timelines is ensuring historical accuracy and chronological consistency between the various levels. Historical recall data are notoriously prone to error (Bernard et al. 1984; Deutscher 1973). Particularly, recall of quantitative data (e.g., “how much did you harvest in that parcel in 1982?”) is known to give unreliable estimates. Furthermore—and this was particularly troubling for us in using a 20-year time horizon—the literature suggests that people are better at

remembering events that occurred recently rather than a long time ago (Bernard et al. 1984). However, ethnologists working on oral history have shown that several data elicitation techniques may improve informant accuracy (Elinson 1963; Kroeger 1983; Ross and Vaughan 1986). Some of these techniques involve a judicious use of cues and probes (Ryan 1996); linking recalls to external events (e.g., events that are unrelated to the theme being studied, but which occurred at the time under scrutiny) (Van Willigen and de Walt 1985); and the use of sequence recalls (Engle 1992).<sup>7</sup> Psychologists know that people often resort to “heuristics” (a cognitive mnemonic process) rather than true episodic recalls when asked to reconstruct past events (Childress et al. 1995). A good enumerator can orient the recall process to facilitate respondents’ use of heuristics, in order to ensure maximum accuracy. Finally, knowing the limitations of recall data, the inferences made from recall information should be conservative so that interpretations do not stretch beyond appropriate bounds. Some researchers for instance have argued that, whereas recall data may be inaccurate for assessing precise quantities for specific variables, it can provide a reliable qualitative picture of what happened, when, and the order in which it happened (Freeman, Romney, and Freeman 1987; McNabb 1990; Ryan and Martinez 1996).

In the plot history methodology, the constant reference to other timelines; the use of particular mnemonic techniques (particularly, heuristics-based time recalls); and the

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<sup>7</sup> Particular activities usually occur within general sequences, and once a general sequence is identified, its component activities are more easily remembered. The cueing may therefore be initially directed at recalling sequences—which are easier to identify—rather than specific activities.



reliance on qualitative data were used to improve the reliability of informants' memories. Validation of the information was done by triangulating with close acquaintances of the informant. We also verified the general consistency of recalls with other sources of historical reconstruction (e.g., confronting the plot history data with results from historical participatory mapping and the evidence provided by historical aerial photos). Finally, discussions were held with La Lima farmers to review our overall results, which in the main received strong support.

## SAMPLING

The sampling strategy had to account for the fact that our sampling unit—the plot—is not a fixed entity through time. Over a 20-year period, not only their use but also their boundaries and their owner may change. Ideally, one would like to stratify the sample on land use at baseline (i.e., in 1975) so that changes in land use from a given baseline could be traced, but this information was not available to us.<sup>8</sup> It was thus decided to randomly sample geographical points in the micro-watershed, as such “points” are independent of history. Once selected, each point was used to specify the plot of which it is part today, and of which it was part in earlier time periods.<sup>9</sup> The present and past managers of the plot were identified so that, if ownership had changed through the period of interest, previous owners would be visited. Thus in all cases an account of the

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<sup>8</sup> Sampling based on today's land use would have been inappropriate, as this creates a sampling bias due to sampling on the dependent variable.

<sup>9</sup> In this sense, the method outlined here might be better referred to as “land point history” rather than “plot history.”

manager's household characteristics was associated with the plot for the year under consideration. Likewise, if the plot of which this point is a part had changed boundaries, then the history of the previous plot was also reconstituted.

Points were identified using simple random sampling. Randomization was done by generating a grid of 20m x 20m, overlaying it on the GIS map, and assigning a sequential ID number to each cell. A random number generation was then performed on the ID series. The geographical coordinates of the centroid for selected cells were identified. The location of each selected point was also reported on an aerial photo in order to identify the present owner and orient the interviewer at time of plot visit.

The sampling of households did not require a particular selection strategy since households were automatically selected for being owners of the plots identified. National and community level data not conveyed by the household survey (such as prices, population and infrastructure) were obtained through compilation of secondary data and a community census.

## ANALYTICAL METHODS

### *Transition Analysis*

We examine changes in land use using transition analysis, a tool originally developed by ethnologists to explore sequences and recurrent patterns in decision making processes (Ryan 1995; 1996; Ryan and Martinez 1995). The study of sequences and recurrent patterns is based on the idea that people confronted by a need for change organize their action on the basis of an implicit scheme suggested by their cultural

experience. This scheme expresses itself in a systematic sequence of actions, which can be empirically observed (Schwarz 1969; Erasmus 1952). In a situation where multiple choices are available, people follow predefined “scripts” organized as a hierarchy of choices. The discovery of such patterns and hierarchies is the goal of transition analysis. To bring this in the context of land use change, the examination of past land use decisions should reveal the underlying patterns implicit in farmers’ behavior and thus, help predict future land use assignments.

### *Econometric Model*

The transition analysis method is based largely on a bivariate description (time vs. land use) of the data using profile and transition matrices (see Results section below). Besides the empirical description they provide, those devices are useful to suggest hypotheses about causes of change. They are not very useful, however, when testing those hypotheses. Econometric analysis is used instead for that purpose. In this section, we present the rationale underlying the econometric model used. The approach is derived from a utility maximization model.

Suppose that households seek to maximize an intertemporal utility function:

$$\sum_{t=0}^{\infty} \beta^t u(c_t)$$

where  $c_t$  is consumption in period  $t$ , which is equal to

$$c_t = y_t - p_k(k_t - k_{t-1}) - C(l_{t-1}, l_t)$$

$y_t$  is farm profit in year  $t$ ,  $k_t$  is a vector of farm assets in year  $t$ , and  $C(l_{t-1}, l_t)$  is the cost of shifting from land use vector  $l_{t-1}$  in year  $t-1$  to land use vector  $l_t$  (separate element  $l_{it}$  of the vector for each plot  $i$  owned by the household) in year  $t$ . Note that if  $C(l_{t-1}, l_t) = 0$  for all  $l_{t-1}$  and  $l_t$ ,  $l_t$  will be independent of  $l_{t-1}$ . In other words, sunk costs of changing land use cause state dependence in land use.

Farm profit is determined by aggregating the profits from each plot ( $i$ ):

$$y_t = \sum_i (p_{y_i} f_i(x_{it}, l_{it}, k_{it}, z_{it}, z_{ht}, z_{vt}) - p_x x_{it})$$

where  $p_{y_i}$  is the price of the output produced on plot  $i$ ,  $p_x$  is the vector of input prices,  $f_i$  is the production function for plot  $i$ ,  $x_{it}$  is a vector of inputs on plot  $i$  in year  $t$ ,  $l_{it}$  is the land use on plot  $i$  in year  $t$ ,  $k_{it}$  is the vector of assets allocated to plot  $i$  in year  $t$ ,  $z_{it}$  is a vector of other plot characteristics that may affect productivity (e.g., slope, distance to water, plot quality rank, soil fertility, erosion),  $z_{ht}$  are household level factors that may affect productivity (e.g., human capital), and  $z_{vt}$  are village level factors that may affect productivity (e.g., presence of technical assistance programs).

We assume that due to labor market imperfections, credit constraints, or other market imperfections, the use of some inputs may be constrained; i.e.,

$$x_t \equiv \sum_i x_{it} \leq x_{\max}(k_{t-1}, z_{ht})$$

for some elements of  $x_t$ , where  $z_{ht}$  is a vector of household characteristics that influence such constraints (e.g., family labor endowment, education) and  $k_{t-1}$  is the vector of household assets available at the beginning of the year.

In each year, the farmer's choices include land use ( $l_t$ ), investment ( $k_t - k_{t-1}$ ), and input use ( $x_{it}$ ). Denote the maximized value of the utility function as  $V(\cdot)$ . In year  $t$ , this value function will be a function of the predetermined state variables ( $l_{t-1}$ ,  $k_{t-1}$ ) and all the exogenous variables noted above ( $p_{kt}$ ,  $p_{yt}$ ,  $p_{xt}$ ,  $z_{it}$ ,  $z_{ht}$ ,  $z_{vt}$ ). Given the recursive nature of the problem, the solution must satisfy the Bellman equation (suppressing the dependence on the other exogenous variables):

$$V(l_{t-1}, k_{t-1}) = \max_{l_t, k_t, x_{it}} [u(y_t(x_{it}, l_t, k_t)) - C(l_{t-1}, l_t) - p_k(k_t - k_{t-1})) + \beta V(l_t, k_t)]$$

The solution to this problem will include land use as a function of the predetermined and exogenous variables:

$$l_t(l_{t-1}, k_{t-1}, p_t, z_{it}, z_{ht}, z_{vt})$$

where  $p_t$  is the vector of output, input and asset prices at the local level.

For the econometric work, we assume that local prices of tradable inputs and outputs are determined by lagged values of real national level prices and market access. Local prices of relatively non-tradable inputs and assets whose prices are affected by local demand (such as land and labor) are assumed to be determined by local population level and access to markets. Given these assumptions, land use is a function of the following variables:

$$l_t(l_{t-1}, k_{t-1}, z_{it}, z_{ht}, z_{vt}, p_{t-1}, pop_{t-1}, mkt.access_{t-1})$$

The precise functional forms for  $V(\cdot)$  or  $l_i(\cdot)$  cannot be analytically determined, even if functional forms for the production and utility functions are specified. For simplicity we assume a linear specification for  $V(\cdot)$ .

Suppose that the optimal utility possible for each choice  $j$  of land use on plot  $i$  in year  $t$  (conditional on optimal choice of  $k_t$ ) is given by:

$$V_{ijt} = a_{lj}l_{it-1} + a_{kj}k_{t-1} + \alpha_j X_{it-1} + u_{ijt}$$

where  $X_{it-1}$  is a vector including  $(z_{it}, z_{ht}, z_{vt}, p_{t-1}, \text{pop}_{t-1}, \text{mkt. access}_{t-1})$  and  $u_{ijt}$  represents unmeasured components of utility known to the household.

If  $u_{ijt}$  is independent and has a Weibull distribution, the probability of the household choosing land use  $j$  for plot  $i$  in year  $t$  is:

$$P_{ijt} = \frac{e^{a_{lj}l_{it-1} + a_{kj}k_{t-1} + \alpha_j X_{it-1}}}{\sum_m e^{a_{lm}l_{it-1} + a_{km}k_{t-1} + \alpha_m X_{it-1}}}$$

This is a multinomial logit model, incorporating state dependence (dependence on  $l_{t-1}$ ).

As outlined earlier, variables introduced in the model include national, community, household and plot level variables. The national level variables include indices of real prices of main outputs (maize, vegetables, and beef).<sup>10</sup> Community level variables include village population, market access (whether local road improved), and access to technology (presence of extension programs).

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<sup>10</sup> Price data for inputs were not available in sufficiently long time series to be used in the analysis.

To represent household level conditions, the family labor endowment, household dependency ratio, and a “human capital index” measuring the literacy and skill level of the household members were measured and included.<sup>11</sup> In addition, the major assets available to the household were measured, including the number of plots owned, area of land operated, the value held in farm implements, domestic consumer durables, and the number of large animals owned.

The plot level variables included were the slope, altitude, distance to water sources, distance to road, quality ranking of the parcel relative to the other parcels operated by the household, soil fertility status, perception of severe erosion (landslides), tenure status of the plot (how acquired and whether titled), and previous use of the parcel. Land use in the previous year is incorporated as an explanatory variable because sunk costs (including possibly the costs of learning about a new land use) may cause land use choices to be state dependent, as explained above.

The outcome variable in the econometric analysis represents the major categories of land use found in La Lima, including forest, perennials (mainly coffee), pasture, fallow land, non-irrigated cropland and irrigated cropland, measured as a discrete choice. In total, 97 plots and 1,361 observations were included in the econometric analysis.

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<sup>11</sup> The indices used in the analysis are defined in detail in Bergeron and Pender (1996).

### *Econometric Problems*

Incorporation of the lagged dependent variable into the estimation can produce inconsistent parameter estimates if there is autocorrelation in the error term. One possible reason for autocorrelation is if there is unmeasured heterogeneity across plots; for example, unmeasured differences in plot quality. In this case, the lagged dependent variable will reflect the effect of such unmeasured differences. It may be that land use persists not because there is true state dependence due to sunk costs of changing land use, but because plots are well suited to a particular use and this cannot be fully accounted for by the explanatory variables. This is considered the problem of distinguishing true state dependence from heterogeneity in the literature on dynamic panel data models (e.g., Maddala 1987). We know of no general solution to this problem for discrete choice models such as multinomial logit. In a linear regression model, one could incorporate fixed effects, which would purge the model of any unobserved heterogeneity due to fixed factors. This approach is not available in a multinomial logit context, however, because the fixed effects estimator produces inconsistent parameter estimates in such discrete choice models (Heckman 1981).

As an alternative, we test for true state dependence by excluding the lagged dependent variable and including additional lagged values of explanatory variables (Maddala 1987). State independence implies:

$$P(l_t = j | X_{it-1}) = P(l_t = j | X_{it-1}, X_{it-2}, \dots)$$



The validity of this test is not affected by autocorrelation in the error term. It can be affected if additional lags of the explanatory variables belong in the specification; for example, due to use of lagged prices to form price expectations. For the test, we included additional lagged values only of explanatory variables that vary significantly from year to year and which have a significant impact in the original regression, to reduce problems of multicollinearity with the test. Based on these criteria, we used additional lags for only the household asset variables. We have no a priori reason to expect lags of household assets to affect land use independently of current assets. Thus we will interpret a significant coefficient on lagged values of household assets as well as current values (and of the same sign) as a rejection of state independence. We expect state dependence due to sunk costs to cause coefficients of additional lagged variables to have the same sign as the non-lagged coefficients, because of the persistence it causes.

A second problem that may be caused by unmeasured heterogeneity across plots is the fact that this implies non-independence of repeat observations from the same plot, which causes incorrect estimates of standard errors (generally too small). This problem is solved by using Huber-White robust standard errors corrected for cluster sampling (StataCorp 1997). This allows for more general forms of non-independence than the random effects model, and produces estimates of standard errors that are also robust to heteroskedasticity.

#### 4. RESULTS

The community of La Lima is located in the municipality of Tatumbla in central Honduras, about 35 km from Tegucigalpa, the country's capital city. The community's limits overlap precisely with the micro-watershed, covering approximately 10 km<sup>2</sup> (971 ha). It is characterized by an uneven topography, with altitudes ranging from 800 to 1800 m.a.s.l. Only 12.3 percent of the area has slopes equal or less than 12 degrees inclination; 40.5 percent is between 12 and 30 degrees; and 47.2 percent is above 30 degrees (Figures 2 and 3). The region is characterized by a bimodal rainy season, with an average yearly precipitation of 1,200 mm. Surface water is abundant, including a permanent stream running through the village. The remaining water bodies are seasonal (for additional details on La Lima, see Bergeron et al. 1996; Barbier and Bergeron 1998).

##### COMMUNITY LEVEL CHANGES

Our reconstitution of plot histories covered a period of 20 years (1975-1995). In that time, the subsistence-oriented farming strategies that prevailed at the outset in the community were progressively replaced by the intensive production of horticultural crops using high-input technologies. At the time of the study, 70 percent of farmer's income was generated by the sale of horticulturals, most of which were unknown in that community only a few years earlier.

Many contextual events accompanied this intensification. Local factors of importance include the construction of a seasonal access road in 1985, and its upgrade to an all-weather road in 1992. Extension services were provided on and off by the Ministry

of Natural Resources (SRN) in the late 1970s and early 1980s, and by the nearby Escuela Agrícola Panamericana de Zamorano (EAP) since the early 1980s, with programs directed mainly towards the use of technical inputs, new or improved varieties of crops and soil conservation practices. Note that these focused less on affecting land use than on affecting management practices within already established land uses. A potable water distribution system was also put in place in 1992, allowing some farmers to divert piped water to their fields to grow irrigated crops. No durable organizations were put in place. A producer association was set up by the EAP in the 1980s, but lasted very shortly and is not further considered in this paper.

External events of importance included the opening of a farmer's market in Tegucigalpa in the early 1980s; and a progressive liberalization of the agricultural sector which, starting in 1988, culminated with the Law of Agricultural Modernization of 1992. In the 20-year period between 1975 and 1995 producers saw a rapid increase in demand for commercial crops. This was accompanied by a shift in economic incentives favoring non-traditional commercial crops: relative prices for the latter improved by up to 200 percent over the period whereas they went down by 40 percent for both maize and beans and 10 percent for meat (see Table 1).

## HOUSEHOLD LEVEL CHANGES

Changes in most household conditions were moderate. A yearly population growth rate of 2.5 percent was registered during the period: yet the population density in

**Table 1: Changes in indexes of relative producer prices for main La Lima crops, 1975-1995 (1975 = 100)**

	1975	1985	1995
Maize	100	60	60
Beans	100	112	58
Green beans	100	45	132
Onion	100	88	196
Yellow onion	100	87	111
Cabbage	100	131	251
Meat (beef)	100	144	92

1996 was still at 57 inhabitants per square kilometer, a low level by international standards. We traced little in or out-migration in the community, and most of the population increase was due to natural demographic growth. Several new households were formed, but family size remained slightly above 6 persons per household throughout the period. Average farm size declined substantially, however, from 4.4 manzanas in 1975 to 2.1 manzanas in 1995<sup>12</sup>. Notwithstanding some increases in real estate prices, land remained remarkably well distributed, with more than 90 percent of households in 1996 having access to land, and 76 percent having irrigated plots. With the construction of a new school and expansion of degrees offered, human capital formation and literacy rates increased, albeit modestly.

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<sup>12</sup> The manzana is the traditional land measure, and is approximately equal to 0.7 hectare.

Figure 2. Land use in La Lima microwatershed, 1995

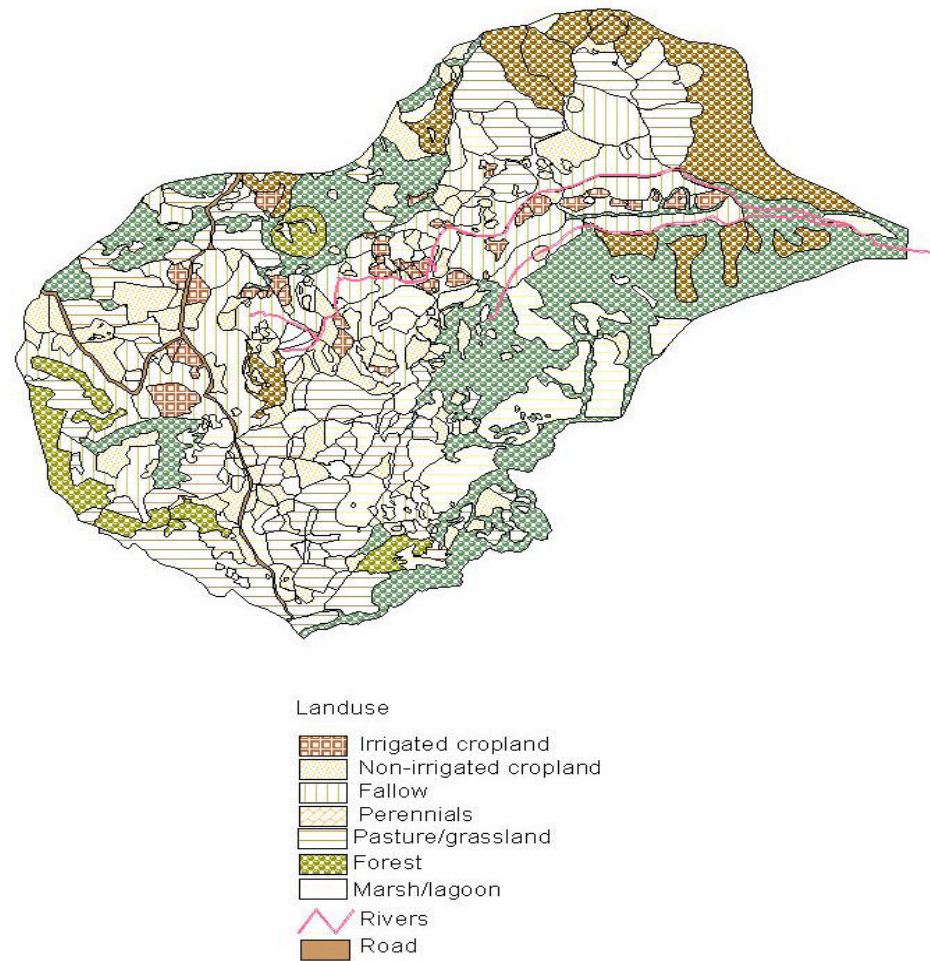
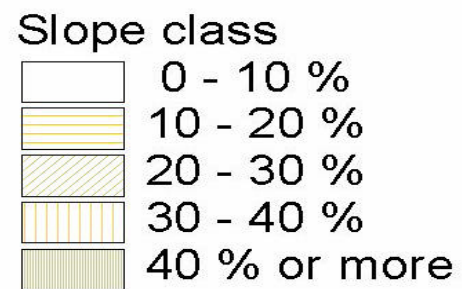
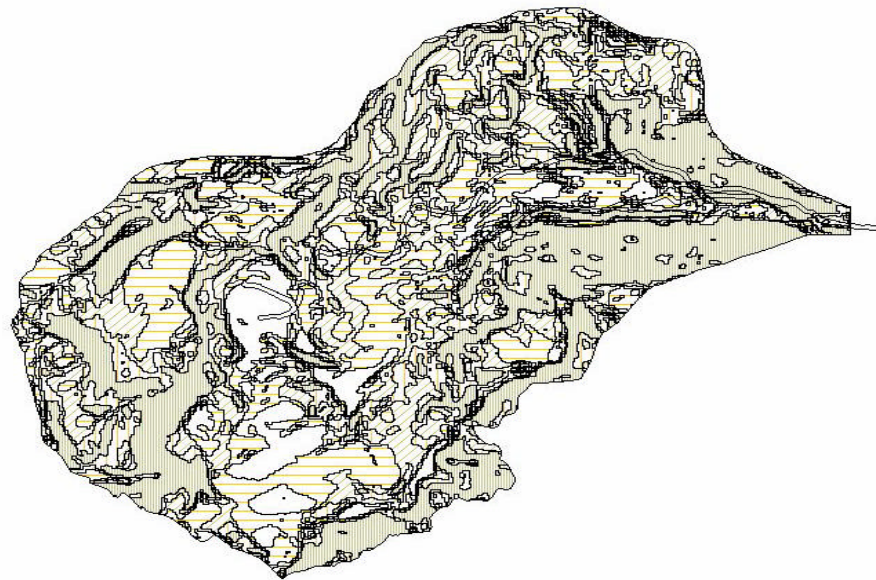


Figure 3. Slope classes in La Lima microwatershed



## PLOT LEVEL CHANGES AND TRANSITION ANALYSIS

The land use data was first organized in a profile matrix to synthesize the broad patterns of changes in the micro-watershed (Figure 4). Confirming the aggregate analysis above, the pattern of land occupation was relatively static throughout the period, with prevailing uses (in terms of area) being forest, non-irrigated cropland and pastures. When looking at the trajectory of plots taken individually, 58 percent of the plots never changed use in the 20 years under study; 30 percent alternated between two states; and only 12 percent were put under more than two uses between 1975 and 1995. A count of the number of “true” transitions<sup>13</sup> occurring in each year shows that most of the plots which changed use did so between 1985 and 1988.

Additional observations are generated by transforming the land use data into a transition matrix (Table 2) where each cell represents the absolute number of transitions from one specific use to another. Note that null values indicate transitions that have not occurred; note also that the diagonal provides information about the relative likelihood of one use remaining the same over time, which is also an indicator of possible path dependence.

Besides highlighting the considerable inertia in land use evidenced by the La Lima data, inspection of Table 2 shows that forest and pasture plots—the most extensive uses—tend to be more static (in relative terms) than cropland uses. As cells below the

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<sup>13</sup> “True” transitions refer to situations when a plot goes from one type of use to another. The term is used to contrast with situations when plots remain under the same use (no transition).

diagonal refer to intensification and cells above the diagonal refer to extensification,<sup>14</sup> then intensification emerges as a notable feature of this period, a finding also confirmed by the comparison of aerial photos from 1975 and 1995 (Bergeron et al. 1996). Second the large number of null values in Table 2 indicate that many transitions have not occurred in La Lima over the study period. The types of uses most prone to change were fallow land and coffee plots (diminishing importance) and irrigated cropland (increasing importance). Note that no new coffee plots were established after 1975—rather, coffee plots were transformed into non-irrigated cropland; and that only one forest plot was converted into another use (non-irrigated cropland)—suggesting that most of the current deforestation had already taken place by 1975. This observation is consistent with results of analysis of aerial photos taken in 1955, 1975 and 1995 (Bergeron et al. 1996). Apparently, intensification took place in already used land and did not involve land clearing.

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<sup>14</sup> Since the categories of land uses in the matrix are ranked in descending order of intensity (irrigated cropland, non-irrigated cropland, fallow; pasture, forest, perennial cultivation), changes noted above the diagonal all refer to a lowering of the intensity of farming.



**Table 2: Transition matrix**

		FROM					
TO		IP	NIP	Fa	Pa	Fo	Pe
	IP	84	12	5	2	0	0
	NIP	5	622	11	10	1	4
	Fa	1	8	111	0	0	0
	Pa	2	15	0	451	0	0
	Fo	0	0	0	0	518	0
	Pe	0	0	0	0	0	61
		92	657	127	463	519	65

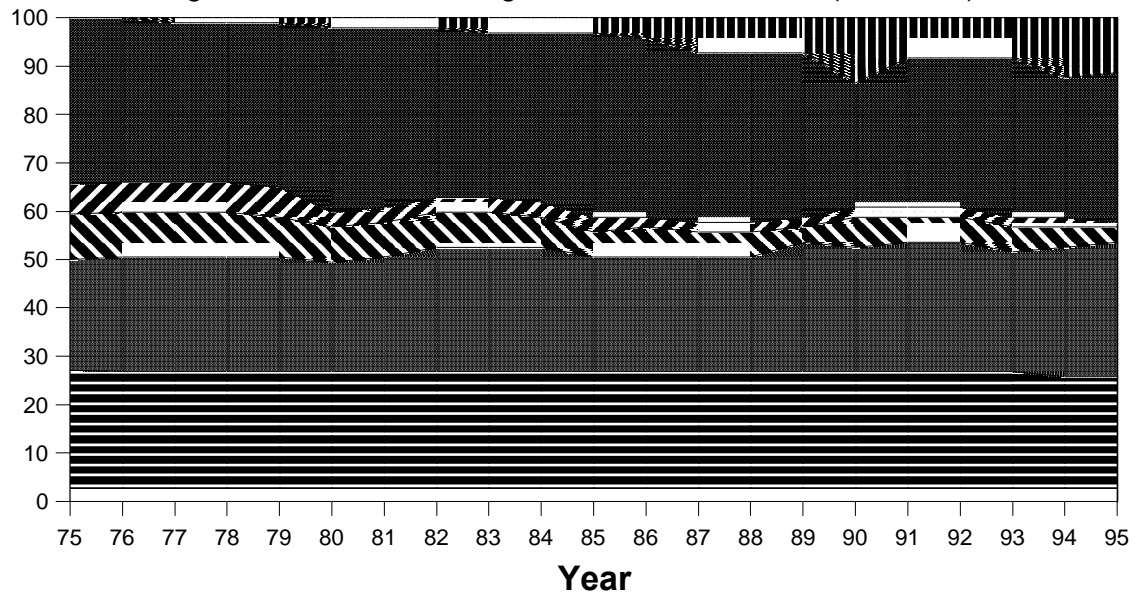
IP: Irrigated permanent cultivation; NIP: Non-irrigated permanent cultivation; Fa: Fallow; Pa: Pasture; Fo: Forest; Pe: Perennials

These various findings are graphically represented in Figures 5a and 5b, which also helps clarify further the sequence in which land use assignments were made, which pathways were most likely to be adopted given previous land use, and what were the main origin and end points of change patterns.<sup>15</sup> At the aggregate level, the only origin use detected in our sample is that of perennial (coffee) agriculture. The main

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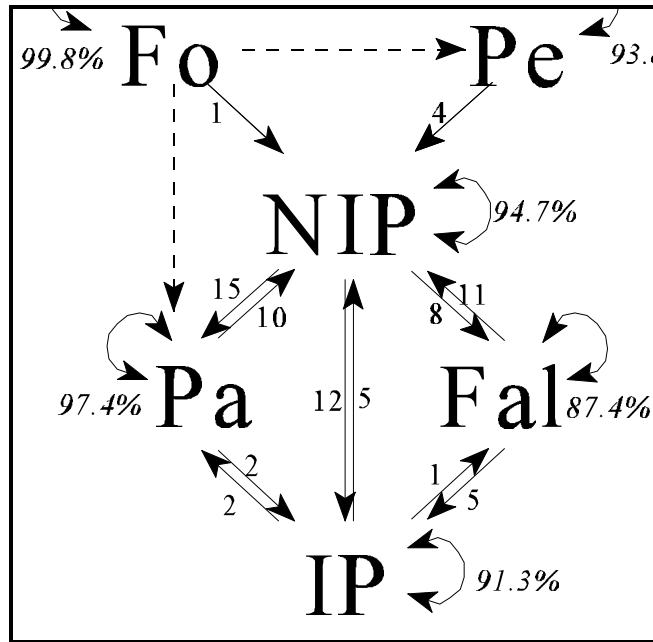
<sup>15</sup> Conventions used in this graph are as follows: the process of land use change involves “origin”, “intermediary” and “end” uses. “Origin uses” occur if the only changes being traced are away from this use; they are denoted by boxed letters. “End uses” signal situations of no return; they are denoted by circled letters. “Intermediary uses” are those that occur in between. Arrows indicate the transitions that occurred and their direction; arrows pointing back at their origin indicate stable states (inertia). Figure 5a presents the complete data, while Figure 5b presents a simplified version of Figure 5a. The rule applied to the construction of the simplified Figure 5b is that a transition type has to represent more than 5 percent of all true transitions occurring in the matrix to be mapped. If less than 5 percent it is viewed as casual and unimportant. We also eliminated “stable state” arrows.

Figure 4: Land Use Change, La Lima, 1975-1995 (% of total)

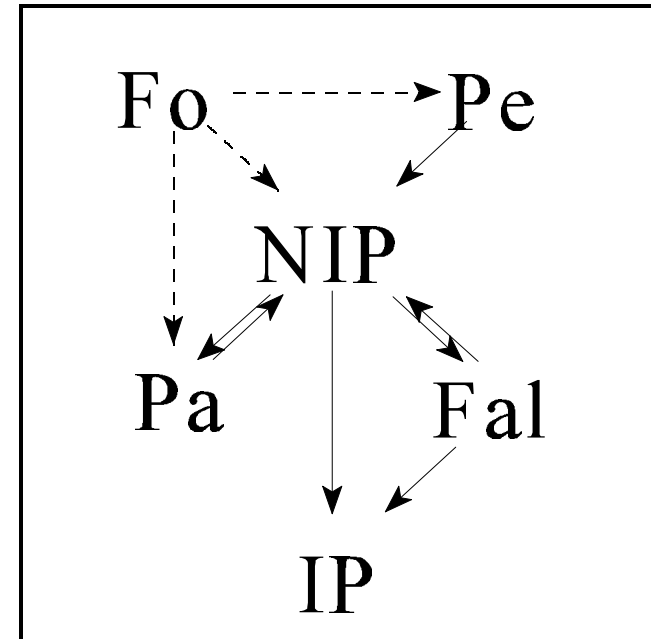


	Irrig. cropland		Non-irr. cropland		Perennials
	Fallow		Pasture		Forest

Fo	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	25	25	
Pa	22	23	23	23	23	22	23	25	25	25	23	23	23	23	26	25	26	26	24	26	27
Fa	9	9	9	9	8	7	7	7	7	6	5	6	5	5	3	6	5	5	5	4	3
Pe	6	6	6	6	6	3	3	3	3	3	3	2	2	2	2	2	2	2	2	1	
No	33	33	32	32	33	37	36	34	33	34	37	36	34	34	33	25	30	30	32	28	30
Irr	0	0	1	1	1	2	2	2	3	3	3	4	7	7	7	13	8	8	8	12	11



**Figure 5a:** Full pathway of change



**Figure 5b:** Simplified pathway of change

IP: Irrigated permanent cultivation; NIP: Non-irrigated permanent cultivation; Fa: Fallow; Pa: Pasture; Fo: Forest; Pe: Perennials

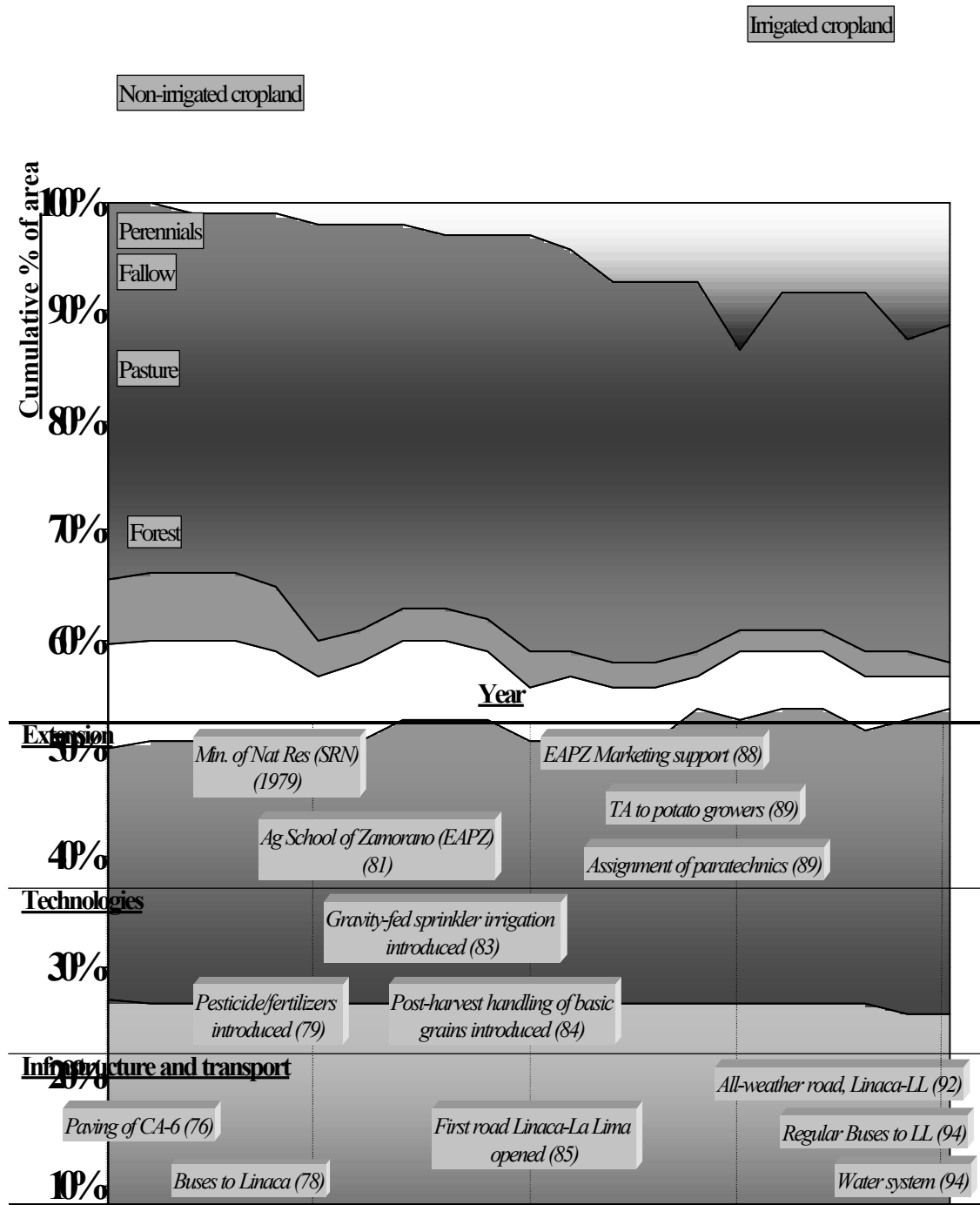
intermediary use is non-irrigated cropland which appears as the crucial transitory use between pasture, fallow and irrigated cropland. The only end use being traced is irrigated cropland, which was to be expected as the levels of sunk investments required by this type of use—e.g., installation of irrigation, infrastructural improvements, etc.—would make any less intensive use a loss of resources.

The last step of our transition analysis consists of graphically overlaying the plot and micro-watershed timelines (Figure 6). The upper part of the graph (which reproduces our earlier Table 1), shows the evolution of land use over the study period. It supports many of our previous insights, i.e., the overwhelming importance of forests, pastures and non-irrigated cropland in the general pattern of land occupation, the relative inertia of land use, the progressive evolution away from coffee and fallow plots towards more intensive uses, and the importance of the period after 1985 in the pace of transitions. It also shows that, even though intensification of irrigated crop production represented the most important event in terms of household incomes and agricultural practices (Barbier and Bergeron 1998), the area involved remained comparatively small (still in 1995, only 14 percent of all the micro-watershed area was actually devoted to intensive irrigated cropping).

The lower part of the graph, which presents the community timeline, allows to suggest some hypotheses as to the impact of exogenous factors in the decision to assign land to particular purposes. First, extension services seem to have been important in the process of intensification. It is not before a road was put into service however that the

Figure 6: Changes in land use and socioeconomic factors

# Timeline of changes in land use and the economy, La Lima Honduras, 1975-1995



transition to horticultural cropping really took momentum. The liberalization of prices taking place in the late 1980s and early 1990s was accompanied by another surge in the conversion of land towards intensified uses. In the next section we test the significance of these and other possible causes of change using econometric analysis.

## ECONOMETRIC ANALYSIS

We first present the results of the regressions and some diagnostic tests, then discuss the significance and implications of the results.

### *Regression Results*

Table 3 presents the results of the multinomial logit regression using variables specified earlier.<sup>16</sup>

The plot level factors that have had the most significant association with land use in La Lima are altitude and the means of acquisition of the plot. Higher altitude plots were more likely to be used for non-irrigated cropland or perennials and less likely to be fallowed, relative to use as irrigated cropland. Purchased plots were more likely than inherited plots to be used in any land use other than irrigated cropland, implying that

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<sup>16</sup> Note that the model does not include lagged values of the land use variables, because of insufficient variation in some types of land use over time. As mentioned earlier, as much as 58 percent of all plots in the sample did not change use at all. Even in those plots that saw most change over the study period, land use change was a relatively infrequent event. As a result, lagged values end up predicting current use almost perfectly, in effect making the model non-estimable. Before discarding lagged values, however, we tested for state dependence (see below). Since we find little evidence of it, the specification in Table 3 would still be the preferred one, even if the model were estimable with lagged land use.

inherited plots were more likely to be used for irrigated cropland. Other plot level factors associated with land uses include slope (higher slope increases likelihood of forest use), distance to the nearest road (fallow less likely and forest more likely far from road), and the size of the plot (larger plots more likely to be in pasture).

The most significant household level factors affecting land use were human capital, number of plots owned, and area farmed. Greater human capital is associated with greater use of irrigated cropland relative to all other land uses. Greater number of plots is associated with greater use of land for perennials and forest. Greater farmland area is associated with greater use of fallow and perennials. Other household level factors associated with land use include ownership of farm equipment and domestic assets, both of which are associated with less use of perennials relative to irrigated cropland.

The only community level factors significantly associated with any land uses were technical assistance programs (both the government programs of the former Secretaría de Recursos Naturales (SRN) and the programs of the Escuela Agrícola Panamericana (EAP)), which had a very strong association with use of land as irrigated cropland, relative to any other use. Interestingly, neither population growth nor access to roads were significantly associated with any land uses. Neither were any of the national level prices.

### *Diagnostics*

The extent of multicollinearity among the explanatory variables was investigated, using variance inflation factors (Chatterjee and Price 1991).<sup>17</sup> Two variables have high variance inflation factors and statistically insignificant coefficients in the regression—village population and the price of beef. Excluding these variables, multicollinearity is not a problem among the remaining variables. All of the statistically significant coefficients in Table 3 are robust (i.e., still statistically significant and with the same sign) to exclusion of these two variables, and with very similar magnitudes.<sup>18</sup> A few additional coefficients are significant (and of the same sign with similar magnitude as in Table 3) in the alternative specification, including farm equipment and road construction as predictors of fallow, road improvement as a predictor of perennials, and the prices of potatoes and onions as predictors of non-irrigated land use.

We also included the soil fertility and soil erosion index variables as explanatory variables in one specification, but do not report the results because the coefficients on these variables suggest that endogeneity of these variables is a problem.<sup>19</sup> For example,

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<sup>17</sup> The variance inflation factor (vif) is defined as  $1/(1-R_j^2)$ , where  $R_j^2$  is the square of the multiple correlation coefficient resulting when explanatory variable  $j$  is regressed against all of the other explanatory variables. A common rule of thumb is that multicollinearity may be a problem if any variables have a greater than 10 (Chatterjee and Price).

<sup>18</sup> Regression results available from the authors upon request.

<sup>19</sup> Endogeneity of sharecropping to land use was also considered to be a problem, so this was not included as an explanatory variable. Sharecropping is never associated with some land uses (irrigated cropland and forest), which also creates technical problems for the multinomial logit estimation.



**Table 3 Determinants of land use<sup>1</sup>**

Multinomial logit regression (robust standard errors) <sup>2</sup>					
Explanatory variable <sub>t-1</sub>	Non-irrigated cropland <sub>t</sub>	Fallow <sub>t</sub>	Pasture <sub>t</sub>	Perennials <sub>t</sub>	Forest <sub>t</sub>
<b>Plot-level</b>					
Slope (degrees)	0.00114	0.04715	0.02341	0.04975	0.08194**
	-0.02252	-0.02839	-0.02889	-0.02578	-0.02517
Altitude (m.a.s.l.)	0.01010**	-0.01052**	0.000545	0.007903*	0.01044**
	-0.00349	-0.0027	-0.002856	-0.003473	-0.00388
Distance to water (km.)	0.1905	0.8817	-0.0321	0.8786	-0.4116
	-0.522	-0.6663	-0.565	-0.8606	-1.0053
Distance to road (km.)	0.711	-1.368**	0.159	0.7768	1.672*
	-0.5744	-0.368	-0.556	-0.6427	-0.671
Cultivable area of plot (manzanas)	0.1742	0.2417	0.6701**	-0.719	-0.2853
	-0.2152	-0.3855	-0.2143	-0.622	-0.6036
Purchased plot (c.f. inherited)	2.503**	2.084*	1.6026*	3.270**	2.611
	-0.842	-0.932	-0.7494	-0.973	-1.411
Plot quality rank (1=highest rank)	0.4321	0.3605	0.6233	0.184	0.9132
	-0.5034	-0.5885	-0.5111	-0.7629	-0.5214
<b>Household-level</b>					
Number of plots owned	0.1401	-0.2326	-0.0873	0.6178**	0.5920**
	-0.1348	-0.1782	-0.1298	-0.1882	-0.1464
Farm equipment index	-0.01324	-0.0165	-0.004939	-0.03181**	-0.001586
	-0.00841	-0.00884	-0.007116	-0.01104	-0.009319
Domestic assets index	0.00674	0.02578	-0.03108	-0.08121*	-0.04839
	-0.02585	-0.02496	-0.02783	-0.03346	-0.03415
Family labor index	0.0043	0.1545	0.3978*	-0.0888	0.04994
	-0.1363	-0.1323	-0.1738	-0.2318	-0.20824
Farm animals index	0.06058	-0.04754	0.07711	-0.09794	-0.05658
	-0.05135	-0.05341	-0.04952	-0.06896	-0.07061

Multinomial logit regression (robust standard errors) <sup>2</sup>					
Explanatory variable <sub>t-1</sub>	Non-irrigated cropland <sub>t</sub>	Fallow <sub>t</sub>	Pasture <sub>t</sub>	Perennials <sub>t</sub>	Forest <sub>t</sub>
Area farmed	0.05014	0.1331*	0.04917	0.1633*	0.03318
	-0.05462	-0.0618	-0.05415	-0.0665	-0.06106
Human capital index	-1.581**	-1.732**	-0.9383*	-1.958**	-1.8757**
	-0.593	-0.579	-0.4396	-0.711	-0.5748
Dependency ratio	1.215	0.452	0.5604	1.682	0.1062
	-1.469	-1.771	-1.2372	-2.996	-2.5816
<b>Microwatershed-Level</b>					
Village population	-0.002849	-0.01619	0.004647	0.00626	0.02092
	-0.009074	-0.01054	-0.009636	-0.01487	-0.01063
Road constructed	0.0142	-1.198	-0.3514	-0.2488	-0.0081
	-0.7796	-0.998	-0.7568	-0.8285	-0.7732
Road improved	-0.6725	-1.334	-0.563	-1.51	-1.024
	-1.0726	-1.314	-0.9992	-1.072	-1.035
Presence of Secretaría de Recursos Naturales (SRN) program	-18.61*	-19.70*	-19.52*	-19.95*	-20.16*
	-8.58	-8.46	-8.6	-8.86	-8.59
Presence of Escuela Agrícola Panamericana (EAP) program	-19.64*	-19.60*	-20.56*	-20.34*	-20.96*
	-8.45	-8.53	-8.47	-8.68	-8.47
<b>National-Level</b>					
Maize real price index	0.02366	0.02287	0.02119	0.02398	0.02351
	-0.02617	-0.02638	-0.02385	-0.02697	-0.02442
Potato real price index	-0.01769	-0.01026	-0.01051	-0.01265	-0.0118
	-0.01298	-0.01485	-0.01278	-0.01489	-0.01387
Onion real price index	0.0311	0.00773	0.01976	0.02558	0.02773
	-0.01975	-0.01844	-0.01823	-0.02076	-0.0191
Beef real price index	-0.01013	0.01112	-0.00974	0.00117	-0.02036
	-0.05003	-0.05323	-0.04829	-0.04929	-0.0486

\* and \*\* indicate statistical significance at the 5% and 1% level.

<sup>1</sup> Pseudo R<sup>2</sup> = 0.456. Omitted category is irrigated cropland. There are 1,361 observations for 97 plots. The intercept is not reported.

<sup>2</sup> Standard errors are robust to non-independence of errors within the same plot and heteroscedasticity.

landslides are found to be positively associated with irrigated cropland use relative to all other uses. This may be because the land suitable for irrigation is more prone to landslides, being located on alluvial soils close to the stream running through the village, or because irrigation contributes to landslides rather than the other way around. Similarly, we find that fallow is positively associated with soil fertility, probably because the decision to fallow contributes to fertility, and not the reverse. Most of the significant coefficients in Table 3 are robust to this alternative specification, and all have the same sign.

As discussed earlier, we tested for state dependence in land use by including additional lagged values of household assets in the specification. Most other variables either vary little over time (e.g., altitude, size of plot) or were insignificant in Table 3 (e.g., price variables), so including additional lags of such variables would not yield a meaningful test. As discussed in an earlier section, if there is no true state dependence, the additional lags should not have significant coefficients (unless there is a true effect of additional lags). If there is true state dependence, the coefficients of the additional lags may be statistically significant, and should be of the same sign as the coefficient of the non-lagged variables.

The results of the test for state dependence are presented in Table 4. We find little support for the hypothesis of state dependence. The coefficient of the additional lagged variable is significant in only a few cases, and in only one case does the explanatory variable and its additional lag both have statistically significant coefficients (for human capital as a determinant of non-irrigated cropland). For some other land uses, only the

additional lagged value of human capital is significant. These results could be due to measurement errors in the human capital variable (i.e., errors in the timing of changes in human capital) or to true lagged impacts of human capital formation. The absence of similar significant lagged effects of other variables does not support the hypothesis of state dependence.

With the exception of coefficients of a few of the asset variables (the effect of family labor on perennials and farm size on pasture), all of the other significant coefficients in Table 3 are robust to the inclusion of additional lags in Table 4. Thus, even if additional lags of variables such as human capital have a true impact and thus belong in the specification, the results are generally robust to this.

### *Discussion of Results*

Direct interpretation of the quantitative implications of the coefficients in a multinomial logit estimation is difficult. To facilitate interpretation, in Table 5 we report the impacts of simulated changes in selected explanatory variables on predicted probabilities of different land uses, based on the estimation results reported in Table 3.<sup>20</sup> The simulation results imply that technical assistance programs have had a major impact on land use, greatly increasing the probability that land will be intensively used as irrigated or non-irrigated cropland, from 27 to over 40 percent. Changes in market prices

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<sup>20</sup> Note that the actual values of all explanatory variables, except for the variable whose impact is being simulated, are used to estimate the mean probability of each land use.

**Table 4 Test for state dependence<sup>1</sup>**

Explanatory variable <sub>t-1</sub>	Multinomial logit regression (robust standard errors) <sup>2</sup>				
	Non-irrigated cropland <sub>t</sub>	Fallow <sub>t</sub>	Pasture <sub>t</sub>	Perennials <sub>t</sub>	Forest <sub>t</sub>
Farm equipment index <sub>t-1</sub>	-0.003113	-0.016212	-0.004002	-0.02171	-0.01501
	-0.00851	-0.008874	-0.007952	-0.01254	-0.01021
Farm equipment index <sub>t-2</sub>	-0.01193	-0.000302	-0.00088	-0.01903	0.018308
	-0.00719	-0.008864	-0.008022	-0.01757	-0.009782
Domestic assets index <sub>t-1</sub>	-0.01015	-0.04827	-0.03605	-0.09729**	-0.06443**
	-0.01702	-0.03059	-0.01908	-0.02411	-0.022
Domestic assets index <sub>t-2</sub>	0.02035	0.08035*	0.00408	0.00031	0.00535
	-0.0194	-0.03167	-0.01825	-0.03365	-0.03187
Family labor index <sub>t-1</sub>	0.0992	0.7039	0.2861	0.5995	0.1342
	-0.39	-0.5199	-0.4074	-0.4462	-0.3816
Family labor index <sub>t-2</sub>	-0.086	-0.5441	0.1187	-0.7168	-0.0972
	-0.3651	-0.5448	-0.3725	-0.4457	-0.3407
Farm animals index <sub>t-1</sub>	0.03665	0.02678	0.01814	-0.00611	-0.02549
	-0.01893	-0.02619	-0.02859	-0.05793	-0.02478
Farm animals index <sub>t-2</sub>	0.03797	-0.07588	0.07457	-0.10209	-0.04289
	-0.05449	0.05962)	-0.05503	-0.06641	-0.07044
Area farmed <sub>t-1</sub>	-0.00251	0.08744	0.03781	0.16151*	0.01356
	-0.06246	-0.05334	-0.0526	-0.07314	-0.06879
Area farmed <sub>t-2</sub>	0.05064	0.05212	0.00588	0.01565	0.02323
	-0.08306	-0.0758	-0.07459	-0.07975	-0.08675
Human capital index <sub>t-1</sub>	-1.0209*	-1.0349*	-0.6813	-0.526	-0.872
	-0.4191	-0.4763	-0.376	-0.4649	-0.4974
Human capital index <sub>t-2</sub>	-0.8737*	-1.0772	-0.5324	-1.7047**	-1.4412**
	-0.3954	-0.5882	-0.2728	-0.598	-0.3748

\* and \*\* indicate statistical significance at the 5% and 1% level.

<sup>1</sup> Pseudo  $R^2 = 0.463$ . Omitted category is irrigated cropland. There are 1275 observations for 97 plots. The intercept and coefficients of other explanatory variables are not reported.

<sup>2</sup> Standard errors are robust to non-independence of errors within the same plot and heteroscedasticity.

also appear to have been quite important. For example, the large increase in potato prices (which more than doubled in real terms) between 1975 and 1995, increased the predicted probability of irrigated cropland use from 7 to 28 percent, with a similar decline in the likelihood of non-irrigated cropland, and limited impact on other uses. In other words, changes in potato prices promoted bringing irrigation to plots already used as cropland, a finding already suggested earlier by the transition analysis. Road construction and improvement, declining farm size, and increasing human capital have also contributed to intensified land use, increasing the likelihood of both irrigated and non-irrigated cropland, relative to other land uses. However, the magnitude of the impact of these variables, especially human capital, is much less than the impacts of technical assistance or changes in the potato price.

**Table 5 Impacts of selected variables on predicted probabilities of different land uses<sup>1</sup>**

Scenario	Mean predicted probability					
	Irrigated cropland	Non-irrigated cropland	Fallow	Pasture	Perennials	Forest
Using actual values for all variables	0.061	0.359	0.063	0.251	0.04	0.226
Technical assistance						
- Without any technical assistance	0	0.273	0.059	0.324	0.049	0.295
- With Secretaría de Recursos Naturales (SRN) program	0.04	0.413	0.04	0.268	0.028	0.212
- With Escuela Agrícola Panamericana (EAP) program	0.067	0.368	0.075	0.232	0.04	0.217
Road						
- Without road	0.05	0.339	0.09	0.262	0.041	0.218
- With unimproved road	0.061	0.383	0.047	0.237	0.038	0.234
- With improved road	0.093	0.391	0.028	0.261	0.02	0.207
Market prices						
- 1975 potato price	0.069	0.342	0.064	0.257	0.04	0.228
- 1995 potato price	0.283	0.119	0.064	0.287	0.039	0.207
Farm size						
- 1975 average farm size	0.01	0.245	0.181	0.173	0.271	0.12
- 1995 average farm size	0.04	0.337	0.095	0.234	0.081	0.214
Human capital						
- 1975 average human capital	0.056	0.383	0.058	0.235	0.036	0.232
- 1995 average human capital	0.062	0.377	0.056	0.245	0.035	0.226
- Minimum human capital	0.019	0.417	0.081	0.157	0.052	0.274
- Maximum human capital	0.335	0.192	0.012	0.368	0.009	0.084

<sup>1</sup> Mean of predicted probabilities of land uses using actual values of all explanatory variables for the sample, except the variable whose impacts are simulated. For those variables, the actual values are replaced by the values indicated in the table (e.g., the average farm size in 1975 and 1995).

It is important to note that these implications are subject to uncertainty in the value of the coefficients estimated in Table 3. This is particularly true for variables whose coefficients have large standard errors relative to their magnitude, such as roads and market prices. Thus we should not take the simulation results too literally; they are only an indication of the relative importance of different factors, assuming the estimated regression coefficients to be correct. We have more confidence in these relative magnitudes for variables such as technical assistance or human capital, whose coefficients are more statistically significant, than for others.

Leaving aside this caveat, these results suggest that the process of agricultural intensification in La Lima has been mainly technology- and market-driven.<sup>21</sup> This is generally consistent with our initial hypothesis, based upon the participatory research and bioeconomic modeling work in the village reported in other papers (Bergeron et al. 1996; Barbier and Bergeron 1998).

The relatively small (and statistically insignificant) impact of road development was not expected. Part of this may be due to multicollinearity problems discussed above. The road construction variable is highly correlated with the population variable,<sup>22</sup> and this

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<sup>21</sup> The results for technical assistance are based on the coefficients of dummy variables whose values are 1 in years when the technical assistance programs were present in La Lima, and 0 in other years. Other unobserved factors (besides technical assistance) that differed between the years in which technical assistance was present and when it was not could also be responsible for the large impact of the dummy variables. We have tried to control for as many such confounding factors as possible (e.g., population growth, road construction, price changes), but this does not rule out all possible alternative explanations.

<sup>22</sup> The correlation coefficient is 0.865.



reduces the ability to discern the separate impact of either variable. Recall that when the population variable is dropped from the regression, road construction was found to have a significant negative association with fallow use. However, the magnitudes of the coefficients were not much different, so the multicollinearity problem would not explain the quantitatively small impact of the road variable, even if it does explain its statistical insignificance. Perhaps the road had limited impact on land use because relatively non-perishable irrigated crops (mainly potatoes and onions) were already being produced in La Lima prior to the road development. Nevertheless, it may have had much greater impact on crop choice on irrigated land (for example, promoting greater production of perishable vegetables such as tomatoes), input use, and incomes. Since this study looks at land use choices, not crop choices or input use, this cannot be explored here; yet it is worth further exploration.

Controlling for the presence and condition of the road, the distance of the plot to the road also has a significant impact on some land uses. Not surprisingly, forests are more likely to be preserved further from the road. Surprisingly, however, fallow is more likely closer to the road. This may be because fallow land is subject to tenure insecurity in more remote areas, or because the investment requirements to clear and use fallow land discourage this practice in remote areas. These are only *ex-post* hypotheses, however.

The insignificance of the coefficient of the population variable in the regression is probably due (at least in part) to the problem of multicollinearity discussed earlier.<sup>23</sup> The

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<sup>23</sup> We did not simulate the impacts of population growth, because of the very low statistical significance of the coefficients.

negative effect of road construction on fallow use found when population was excluded from the regression could be due to the effect of population growth being “picked up” by the road variable, or due to the combined effect of road construction and population growth on fallow use. Thus, there appears to be some degree of population and/or market induced reduction in fallow use, although we cannot disentangle the two.

A factor usually related to population growth, though surprisingly not highly correlated with it in our data, is farm size.<sup>24</sup> As one would expect (Lowe et al. 1992), we find that larger farms are more likely to keep land in more extensive (or “traditional”) uses, such as fallow and perennials. To the extent that population growth has been responsible for declining farm sizes in La Lima, it has contributed to intensification of annual crops in place of such extensive uses. However, given the low correlation between population and farm size, other factors may be more responsible for declining farm sizes in La Lima. For example, labor or capital constraints in the context of improved economic opportunities may have caused farmers to operate less land, rather than population pressure. Thus the indirect impact of population growth on intensification in La Lima has been unclear.

The positive impact of human capital on adoption of irrigated farming suggests that technical assistance promoting intensive irrigated agriculture either was targeted towards more experienced or educated farmers, or found a more receptive audience among such farmers. Without farm level data on participation in technical assistance programs, we cannot distinguish between these two explanations, though it would be

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<sup>24</sup> The correlation coefficient is -0.006.

useful to try to do so in future research. Although the average impact of human capital formation on intensification was relatively small due to the limited increase in average human capital, as noted above, the impacts of human capital investment in particular households could have been quite large. For example, an increase in the human capital index from the minimum to the maximum level would increase the average probability of irrigated cropland use from 2 percent to 34 percent, with a comparable reduction in the probability of non-irrigated use. Thus, investments in human capital could be very complementary to technical assistance programs in fostering adoption of irrigated crops.

Land tenure relations also appear to have an important influence on land use intensification. Inherited plots are much more likely than purchased plots to be used for irrigated crop production. This could be due to greater tenure security on inherited plots, facilitating access to credit and willingness to make land improving investments, as has been argued in numerous other studies (e.g., Feder et al. 1988; Place and Hazell 1993). This result is consistent with the findings of Lopez (1996), who found that land titling programs in the departments of Santa Barbara and Comayagua in Honduras significantly increased farmers' access to credit, use of modern inputs, investments in land improvements, and farm incomes. Our results also might be due to inherited plots being of higher land quality because farmers keep their best plots in the family. Note however that we do control for various measures of land quality such as slope and plot quality rank

but do not find any evidence of significant differences in these measures of quality between inherited and purchased plots.<sup>25</sup>

The possibly large but statistically insignificant impact of market prices in the estimation results suggests the need to conduct this study in a larger number of villages and in different countries, to be able to identify such effects with confidence. The variation in prices is only over time and not across plots or households, so that these variables are not able to account for any of the cross sectional variation in land use within the sample. The same is true of all of the community level variables as well.

## 5. CONCLUSION

We began this paper by saying that our intent was twofold: first, examine in general terms the applicability and usefulness of the plot history method to the study of land use change; second, use the method to evaluate the patterns of land use changes and their causes in a community whose pattern of development over the past few decades was characterized by a process of horticultural intensification. An associated goal of the latter was to derive the policy implications of the findings.

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<sup>25</sup> Purchased plots have slightly higher average slope and lower average plot quality rank, though the differences are not statistically significant.

## SUMMARY OF FINDINGS

In the descriptive analysis, we found that the pattern of land use in La Lima was relatively static—in fact, change between years was the exception rather than the norm. This was found to be particularly the case in areas under extensive use such as pastures and forests. In certain areas however, a rapid process of intensification was identified, although the total area affected remained relatively small, with only 14 percent of the microwatershed actually being transformed into intensive, irrigated croplands.

In the econometric analysis, land use intensification was found to be influenced by plot level variables such as altitude, slope and tenure; by farm level variables such as human capital, farm size, and ownership of productive implements; and by community variables such as technical assistance, roads and population growth—although the latter two could not be disentangled because of high correlation between these factors. The relative importance of each variable fluctuated with land use types and with the direction of change, but the findings generally supported our conceptualization of the factors leading up to land use change.

## POLICY IMPLICATIONS

Broader application of the study method in a larger number of communities representing different pathways of development is needed to assess broader policy implications. Thus any implications can only be tentative.

To the extent that the findings of this study are representative of the horticultural intensification pathway, they suggest that there may be opportunities to foster similar

income enhancing development in communities having similar characteristics through technical assistance programs elsewhere in Honduras. Findings from a recent survey of 48 communities in central Honduras suggest that at least 5 percent of the region has conditions favorable to horticultural intensification, and that the presence of technical assistance programs has been relatively low in such areas (Pender et al. 1999).

The importance of human capital in favoring irrigated crop development, in combination with technical assistance, suggests the importance of investments in education as a complementary input to technical assistance programs. Investments in education have also been relatively low in the horticultural intensification pathway (*ibid.*), so there are likely large opportunities here as well.

Improvements in land tenure security and access to credit could also increase investments in irrigated cropland. It is not clear from our results whether a land titling program would be helpful in this regard, since there were very few titled plots in our sample. It may be that *de facto* tenure security is only acquired through long term use of a plot, which is reflected by the difference between inherited and purchased plots in our sample. Thus there may be no policy intervention required, although the potential for increasing tenure security through land titling should be investigated in other communities where such programs have been implemented.

The findings with respect to farm size suggest the importance of small farmers having access to land to be able to take advantage of profitable opportunities for intensification of irrigated crops. In La Lima, the process of intensification and its equity appears to have been facilitated by fairly broad access to irrigable land. In communities

where land is much more unequally distributed, intensification may be stalled and its benefits certainly more unequal than in the case of La Lima.

The apparently large impact of some price changes on land use suggests that structural adjustment programs and market liberalization have also been important contributors to adoption of higher value irrigated crops. However, we cannot be very confident in this conclusion, because of the low statistical significance of most of the price coefficients. The importance of other local level factors suggests that market liberalization may not be sufficient condition to take full advantage of opportunities for more intensive or profitable agriculture, although it appears to have contributed.

While we do not address the outcomes of land use change for productivity, sustainability of resource use, environmental impacts, or poverty in this paper, results from other studies in La Lima combined with these results suggest that some tradeoffs may exist between productivity and income generation on one hand, and sustainability and environmental impacts on the other. Adoption of intensive irrigated crop production has increased farm productivity and incomes substantially (Barbier and Bergeron 1998), but it also is associated with the decline of less erosive land uses such as perennial crops and fallow, and with increased use of agricultural chemicals, which are contributing to water pollution downstream of the village (Bergeron et al. 1996). Measurements of erosion in La Lima indicate that the problem is not major overall (Barbier and Bergeron 1998), but parts of the watershed (particularly the irrigated part) are subject to major

landslides in years of heavy rainfall.<sup>26</sup> It is not known, however, the extent to which irrigated crop production contributes to the landslides, or only happens to occur where the land is prone to such events. Furthermore, simulation results of a bioeconomic model for La Lima suggest that intensified crop production has reduced erosion pressure in the upper parts of the watershed, by reducing farmers' extensive production of maize in those areas (Barbier and Bergeron 1998). Thus, the impacts of irrigated crop intensification for resource sustainability and the environment are not entirely clear, and not all necessarily negative. There may be some complementarities as well as tradeoffs between environmental and income objectives in this development pathway.

## RESEARCH IMPLICATIONS

We have demonstrated the feasibility and utility of using historical recall data to reconstruct histories of changes in land use and associated causal factors. By using various data elicitation techniques to improve recall, we believe we have been able to produce reasonably reliable measures of qualitative changes in land use and causal factors. The recall data was broadly supported by the comparison with historical aerial photos (1975 and 1995) which depicted similar trends as the ones observed through the plot history method. The acceptance by local residents of our reconstructed timelines also comforts us that the data collection method provided an accurate description of land

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<sup>26</sup> This was evident even before Hurricane Mitch. For example, in the heavy rainfall year of 1996, while our study was ongoing, a major landslide occurred in the irrigated part of the microwatershed, displacing land by as much as 2 meters and completely destroying some plots.



use change in that community. Respondents, however, may have had difficulties in recalling the exact year of some changes (particularly in household characteristics), which may account for the significant impacts of adding additional lags of some of these variables in the econometric analysis.

In future applications of this method, it may be preferable to restrict the recall period to the more recent past; such as the past 10 years. As important as the length of the recall period, however, is the existence of well known events in particular years to anchor respondents memories, and the availability of historical aerial photographs and other secondary information to help validate the results.

We have been able to identify several interesting empirical findings in this study of a single community, even with respect to some community level variables. The real power of the method will only be demonstrated, however, when it is applied in a substantial number of communities, allowing clearer identification of the impacts of community and higher level factors on land use change. It would be particularly useful to apply this method in communities representing different development pathways (as have been identified in central Honduras) to investigate whether the key causal factors and dynamics of land use change are different in different development pathways, and thus whether different policy, institutional and technology strategies are called for in different pathways. We intend to pursue these lines of enquiry in future research in Honduras and elsewhere.

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